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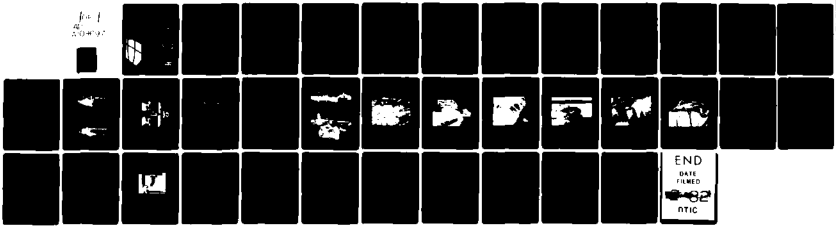

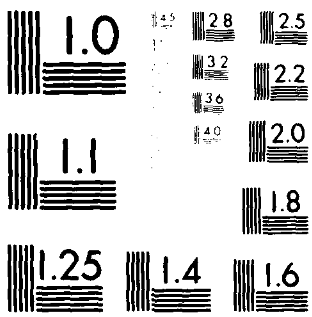

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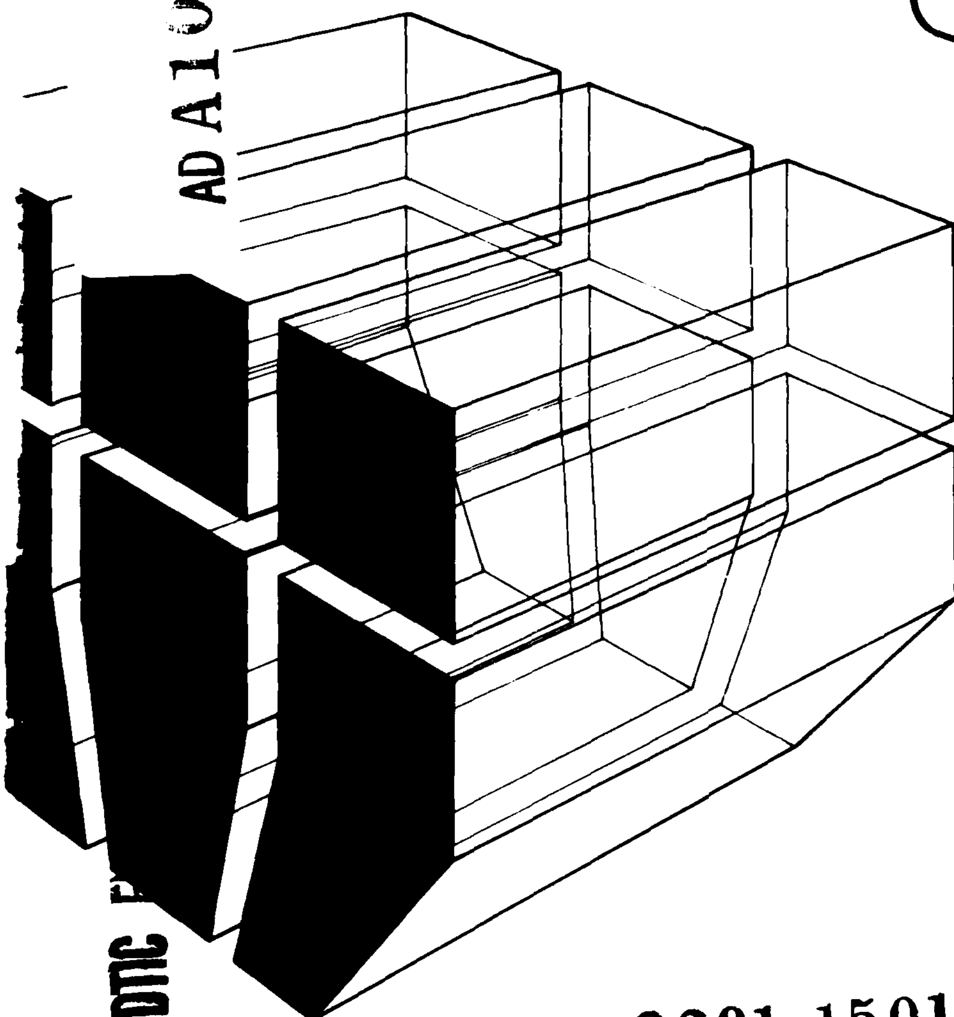
TECHNICAL REPORT M-301
October 1981
Field Welding of Aluminum Alloys

IDENTIFICATION OF PROBLEMS ENCOUNTERED IN THE FIELD WELDING OF ALUMINUM



by
R. A. Weber

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CERL-TR-M-301	2. GOVT ACCESSION NO. AD-A109	3. RECIPIENT'S CATALOG NUMBER 677
4. TITLE (and Subtitle) IDENTIFICATION OF PROBLEMS ENCOUNTERED IN THE FIELD WELDING OF ALUMINUM		5. TYPE OF REPORT & PERIOD COVERED FINAL
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. A. Weber		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. ARMY CONSTRUCTION ENGINEERING RESEARCH LABORATORY P.O. Box 4005, Champaign, IL 61820		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 4A762731AT41-C-023
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE October 1981
		13. NUMBER OF PAGES 32
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are obtainable from the National Technical Information Service
Springfield, VA 22151

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

aluminum
welding

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report identifies the procedures and equipment used for field welding of aluminum, determines the most common types of failures encountered, determines problems with field welding maintenance, and proposes solutions to these problems. It has been found that the most common damages to aluminum structures are puncturing and tearing. These damages must be repaired in the field in order to keep equipment at a high degree of operational readiness. The repair of such damages requires maintenance personnel skilled in aluminum welding. The results of this investigation show that current training procedures do not produce maintenance personnel with adequate aluminum welding

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skills. In addition, there is a lack of skilled supervisors who can provide adequate on-the-job training to new maintenance personnel. The standardized welding procedure proposed by this investigation will help resolve these problems.

FOREWORD

This investigation was performed for the U.S. Army Engineer School and for the Directorate of Military Programs, Office of the Chief of Engineers (OCE), under Project Number 4A762731AT41, "Military Facilities Engineering Technology"; Technical Area C, "Construction Operations in T/O"; Work Unit 023, "Field Welding of Aluminum Alloys." The U.S. Army Engineer School Technical Monitor is CWO B. Fenhagen.

This investigation was performed by the Engineering and Materials (EM) Division, U.S. Army Construction Engineering Research Laboratory (CERL). Mr. R. A. Weber was the CERL Principal Investigator. Dr. R. Quattrone is Chief of EM.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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IDENTIFICATION OF PROBLEMS ENCOUNTERED IN THE FIELD WELDING OF ALUMINUM

1 INTRODUCTION

Background

The Army has been working toward developing a lighter, more mobile force. As a part of this program, aluminum is being introduced into as many pieces of equipment as possible, since its lighter weight allows for larger-volume loads and faster movement. For this reason, the Corps of Engineers' three major tactical bridging systems use extensive quantities of aluminum. These systems are the mobile assault bridge (MAB), the improved float bridge (ribbon bridge), and the medium girder bridge (MGB).

The U.S. Army Engineer School (USAES) Directorate of Combat Development has received numerous complaints about field problems with weld repairs on these bridges, ranging from poor training to lack of materials. The U.S. Army Construction Engineering Research Laboratory (CERL) conducted this investigation at the request of USAES to determine and devise solutions for these difficulties.

Objective

The objective of this investigation was to identify the procedures and equipment used for field welding of aluminum in order to (1) determine the types of failures encountered, (2) ascertain the problems with field welding, and (3) formulate solutions to these problems.

Approach

First, the procedures and equipment used and the problems encountered with them were identified. This was done through extensive discussions with bridge units, battalion maintenance units, USAES bridging instructors, as well as Advanced Individual Training (AIT) instructors and through observation of maintenance unit equipment and handling procedures. Problem areas investigated included materials used, repair materials available, types of failures encountered, and personnel training. Solutions to these problems were then devised, and a method of disseminating these solutions to the engineer bridge units in a timely, effective manner was determined.

Mode of Technology Transfer

This report will serve as the initial transfer of knowledge. Proponents of the following manuals will issue changes reflecting the information developed under this program: TM 5-5420-209-12, *Technical Manual Operator and Organizational Maintenance Manual Improved Float Bridge (Ribbon Bridge)*; and TM 5-5420-210-12, *Technical Manual Operator and Organizational Maintenance Manual Transporter, Mobile Floating Assault Bridge/Ferry Condec Corp. Model 2270, FSN 5420-491-6330.*

2 SELECTED MILITARY BRIDGING SYSTEMS

Mobile Assault Bridge (MAB)

The MAB consists of three major components: the transporter, the interior bay (bridge) superstructure, and the end bay (ramp) superstructure (Figures 1, 2, and 3). The transporter, an amphibious vehicle mounted on a 4 × 4 chassis, has a riveted and welded hull and a watertight, three-man cab. The hull is constructed of 1/8-in. (8.2-mm) aluminum plate on the sides and deck, and 3/16-in. (4.8-mm) aluminum plate on the bottom, bow, and stern. The interior bay superstructure is constructed of welded steel girders with an extruded aluminum decking, while the end bay superstructure is constructed of aluminum girders and aluminum decking. The aluminum used is 5086 alloy, a magnesium alloy whose strength is developed by strain hardening. Magnesium up to approximately 5 percent makes it a strong, highly weldable material. It has excellent weld joint efficiency because it retains a high percentage of its strength after welding. These properties, plus its good corrosion resistance, make this alloy ideal for bridge structural members.

Improved Float Bridge (Ribbon Bridge)

The ribbon bridge's major components are the transporter, the interior bay pontons (Figures 4 and 5), and the ramp bay pontons (Figures 6 and 7). The transporter is a standard 5-ton truck with a special A-frame for off- and on-loading the bay sections (Figure 8). The interior and ramp bay sections are constructed of four aluminum pontons hinged in three places so that the bays can be accordian-folded during transport. The pontons are fabricated from 5456 aluminum alloy. The decking is 6061 aluminum alloy on both the interior and ramp bays. The major alloying element in the 5456 aluminum is magnesium; like the 5086 alloy,

its strength is developed by strain hardening. It has excellent weldability and high weld joint efficiency. Magnesium and silicon are the major alloying elements of the 6061 alloy; its strength is developed by a thermal treatment after the product has been rolled to the desired shape. The 6061 alloy is one of the most versatile of the heat treatable alloys. It has good weldability, but has a joint efficiency of only about 65 to 75 percent after fusion welding unless a post-weld heat treatment is used.

Medium Girder Bridge (MGB)

The MGB is made up of panels, beams, and girders. Th· parts are transported by trailer (Figures 9 and 10) to the erection site where they are manually assembled into a bridge span (Figure 11). The bridge is completely fabricated from 7005 aluminum alloy (a zinc-magnesium alloy). This alloy i: a natural-aged material, requiring about 1 month afte: fabrication and welding to gain its maximum strength. Its weldability is good, with joint efficiency approaching 90 percent after 1 month. This bridge system is the newest of the three and consequently has been used very little by the troop units.

3 INFORMATION SOURCES

USAES personnel provided background information and discussed their operational experiences with the three bridge systems. USAES bridge school personnel have worked with each bridge system and have been involved with testing the ribbon bridge and the MGB.

The bridge company of the 1st Engineer Battalion, 1st Infantry Division, Fort Riley, KS, has operated and maintained 24 MABs for approximately 6 years. The 15th Engineer Battalion of the 9th Infantry Division at Fort Lewis, WA, operates and maintains 28 ribbon bridge bays and transporters and 12 bridge erection boats and transporters. The 55th Engineer Company (Panel Bridge), 973rd Engineer Group at Fort Riley, KS, received the MGB in October 1979 and had erected the bridge once prior to the discussions.

Additional information concerning the welders, welding training, equipment, and materials was obtained from the 701st Maintenance Battalion, Fort Riley, KS; the 709th Maintenance Batallion, Fort Lewis, WA; and the U.S. Army Ordnance Center and School, Aberdeen Proving Grounds. The Army Ordnance School provides all the basic training in welding for Engineer maintenance personnel.

4 ANALYSIS AND DISCUSSION OF REPAIR REQUIREMENTS

Common Repairs

Mobile Assault Bridge (MAB)

Personnel from the USAES Bridging Instruction Group indicated that the primary failures encountered with the MAB were punctures of the aluminum hull caused by rocky shore lines (Figures 12 and 13). Discussions with the 1st Engineer Battalion indicated that the majority of MAB weld repairs observed are in the deckhouse. When the MAB units are bridging across water and the units and the bays are not aligned properly, the deckhouse can be hit with the end of a bay.

To repair the damage, the sheet aluminum is bent back to the proper shape and the tears are welded. These constitute the majority of the MAB repairs; however, the other repairs, although of lesser number, are more serious from a structural standpoint. For example, the decking pipe supports inside the transporter can be pulled away from the decking, apparently by stresses occurring when the bay superstructure is loaded or off-loaded.

Another type of failure, which appeared to be an isolated incident, occurred in the right wheel well where the bracket holding the exhaust pipe is bolted. A crack started in one of the bolt holes and propagated downward for approximately 3 ft (.9 m). The final type of repair encountered was patching of pun ..es in the hull. These are repaired in one of two ways: either a patch is put over the hole and welded, or the depressed part of the puncture area is pushed out and the slot is welded. On the whole, the MAB requires very little weld repair maintenance.

The Improved Float Bridge (Ribbon Bridge)

The ribbon bridge requires the most repair welding maintenance of all the bridge systems evaluated. Since USAES personnel helped develop the ribbon bridge, they were able to provide information about problems encountered when it was tested. Some of these problems resulted from the rigorous testing and are not expected to occur in service until after years of use. Because the ribbon bridge floats, it also requires repair of punctures in the pontons (Figure 13).

Puncture sources range from backing into a low tree limb to hitting a rock while off-loading to being hit by the launching boat. Other failures occur in both

the brackets and the holes of the bay connectors in the tagline tieoff, in the bay tiedown pin, in the ponton bridge latch, and in the bilge port. The unfolding latch appears to be the major source of these problems. There is a latch at both ends of the pontons. One end is at the center bottom of the ends of the bay; consequently, when the bays are off-loaded in either a fast current stream or in a waterway with a shallow shoreline, one latch bracket may get caught and be damaged. When the bay section is on-loaded, the latch bracket is used to hook the winch to the bay and to lock the bay sections to the transporter. The locking pin is hydraulically operated and if there is even a slight misalignment, the bracket is damaged.

Units are required to maintain a C-1 operational readiness; this means that at least 89.5 percent of the equipment must always be ready for use. Discussions with operating personnel indicated that it is very difficult to maintain readiness, especially during field training exercises. The 15th Engineer Battalion encountered problems with the cable guide and corner pins. The cable guides are subjected to particularly hard use, and when they are damaged, the rest of the equipment becomes inoperable. The transporter and the bay are considered to be one unit; problems with either one can be cause for deadlining. Typically, there are two end-bay and one interior-bay bridge sections deadlined after a field exercise, leaving only 89.29 percent of the 28 bridge sections operational. The primary cause of the deadlining is the cable guide, which is required to bear the stresses from off- and on-loading the bay sections. In swift currents or if subjected to mishandling, this guide can be torn loose, necessitating weld repair or complete replacement. Replacement is a problem because of the supply delay (e.g., one replacement guide did not arrive for 117 days).

The final area of difficulty appears to be a design deficiency. The rollers on the transporter rub against the reinforcing box around the corner pin during on- and off-loading procedures. Eventually, the reinforcement is reduced severely, which reduces the stress-bearing capability. It must then be built up again by welding.

The Medium Girder Bridge (MGB)

The MGB is a new bridge system in the U.S. Army, and has not been erected very often in the United States except by USAES. Therefore, the information obtained on the MGB comes primarily from USAES personnel. The primary failure of the MGB system is in the carrying brackets (Figure 14). Pry bars are inserted into the brackets to lift and place the various pieces of the MGB together. As the pieces are manipulated into place, the carrying brackets take all the stress and are subject to tearing. The technical manual supplied with the bridge by the manufacturer notes which areas of the piece may be welded and the welding procedure that should be used. If failures occur in an unweldable area, then that section must be replaced. The MGB is a unique system in that it uses a weldable, age-hardening aluminum alloy. The 7005 alloy used is a natural-aged alloy; therefore, it loses its strength in the area of the weld because of the heat and requires an aging period of 30 days to regain 90 percent of its strength. As a result, these bridge sections cannot be used immediately after welding; therefore, these parts need not be field-welded.

Welding Personnel

Personnel involved in the repair welding of aluminum lack sufficient training. The welding personnel assigned to Engineer Unit maintenance positions have the military occupational specialty 44B. During their AIT schooling, they learn body and fender repair, glass repair and replacement, painting, and welding. The course is a 12-week, self-paced program, providing very basic information on welding and some hands-on experience with the welding processes. In response to the increased need for personnel who can weld aluminum, the school has been realigned so that students have more instruction time in this area. However, this extra time means reducing time spent in other areas.

When the troops finish AIT school, they know the fundamentals of welding, and they know how to strike and break an arc. Additional training, such as how to set up their equipment and how to vary the parameters to get a better weld are part of their on-the-job training; however, the number of supervising NCOs who have the knowledge to provide this training adequately is very small. Another problem is the difficulty with keeping skilled operators in the Army. The combination of these factors creates a continuous need for welder training at the unit level.

Welding Equipment and Supplies

Three manufacturers produce welding power supplies which are available to an engineering battalion's maintenance company; each is an engine-driven generator delivering 300 amperes of DC welding current. The welding power supplies were originally designed for steel welding and, consequently, are not totally suitable for aluminum welding. A replacement for one of

these power supplies (trailer-mounted unit), which should resolve this problem, is in the procurement stage and is expected to be fielded within 5 years. It is also a DC generator delivering 300 amperes. Direct current is suitable for gas metal-arc welding (GMAW) of aluminum plate (1/4 in. [.63 cm] and thicker) where a great deal of penetration is required, and multiple passes can be accommodated. Alternating current is more appropriate for welding aluminum sheet (less than 1/4 in. [.63 cm]), because the average amount of heat produced is less; however, direct current can be used on thicknesses down to 1/8 in. (.32 cm). The amount of joint preparation is somewhat less with AC, because it has an inherent cleaning action that removes oxides in and beside the weld joint.

The welding gun currently used is a Westinghouse SA-100, 300-ampere, 1-lb spool GMAW gun (Figure 15). It has a 60 percent duty cycle and is suitable for welding aluminum. Aberdeen Proving Ground personnel have had difficulties with the wire feed motor on some of the GMAW guns, apparently because of a substandard batch of motors that burned out easily. The shielding gas used is argon, a fairly heavy gas that will displace air easily but will not be blown away by wind under field-welding conditions.

One problem commonly encountered by maintenance personnel is the lack of aluminum stock to make repairs. The difficulty in obtaining the stock number of available material can cause a long delay in getting a crucial part repaired.

The only type of welding wire available for maintenance use is the 5356 aluminum alloy. It is supplied in 1-lb spools for the Westinghouse gun and has a diameter of 0.045 in. (1.1 mm). The chief alloying element in this filler alloy is magnesium, which is suitable for all types of aluminum used in the bridges.

General Observations

Observations of equipment, personnel, materials, and repair work in the field showed several causes of poor weld quality. Unlike steel, the quality of aluminum welding depends greatly on joint preparation. The joint must be clean, well-shaped, and free of grease, oil, water, and paint. Joint design is important from the standpoints of penetration and side wall fusion. A heavy land section at the bottom of the weld will prevent the equipment from fully penetrating the area where it is needed. If the side walls are too steep or too close together, lack of fusion on the side walls can occur; this is analogous to building a crack right into the structure and can lead to an early failure of the part.

The presence of grease, oil, or other hydrogen-bearing chemicals in or near the weld puddle will be deleterious to the weld metal. The heat of the arc frees hydrogen gas, which then enters the weld metal and causes weld porosity. Porosity sufficient to cause the weld bead to look like "swiss cheese" will severely reduce the weld metal strength, again reducing the life expectancy of the repair. The idea of underwater welding was discussed with the 15th Engineer Battalion because of the extra work now necessary to pull a ribbon bridge bay section out of the bridge and onto shore; this is necessary to gain access to failures that have occurred in an area of the structure below the water level. However, water is a substantial source of hydrogen and therefore obviates the possibility of underwater welding, so this idea was rejected.

Another area of concern is the oxide coating that forms on aluminum. The coating is beneficial in that it gives the aluminum its good corrosion resistance, but it presents a welding problem. Since the oxide adheres very well to the surface of the aluminum and usually does not melt in the heat of the arc, it therefore can become an inclusion in the weld metal. The oxide also attracts and holds moisture, which causes release of hydrogen gas, and therefore, porosity.

Welding Procedure to Alleviate Problems

These observations and the discussions with personnel involved in aluminum welding indicated that a stop-gap measure is required to relieve some of the difficulties observed among supervisors, maintenance personnel, and training personnel. Such a measure would be a standardized procedure to be used by the welder that would incorporate: (1) the proper joint preparation, including cleaning, degreasing, and joint design; and (2) welding parameters, including voltage amperage, gas flow rates and travel speed, and any post-weld considerations, such as mechanically shaping the weld bead. This welding procedure should incorporate the 5086, 5456, and 6061 aluminum alloys. The 7005 alloy used in the MGB is not included because of the specific instructions in the user's manual, the fact that it is an age-hardenable alloy, and the recommendations of the manufacturer that the parts be welded in a shop and that only specific areas can be welded. This proposed welding procedure is attached as an appendix to this report.

5 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The most commonly encountered field damages to aluminum structures are punctures and tearing.

2. The MAB and the ribbon bridge systems are field weldable, but the MGB system, which is constructed of 7005 aluminum alloy, is not field weldable with current technology because of the time required for the age hardening process.

3. Current training procedures are not sufficient to produce skilled aluminum welders. The welders require more thorough training in aluminum joint preparation and welding.*

4. The Army lacks enough skilled NCOs to provide maintenance personnel with the additional on-the-job-training required for welding aluminum.

5. Available equipment can be used for welding aluminum, but aluminum welding requires more operator skill than steel welding.

6. The standardized welding procedure proposed in this report will help improve welding training, supervision, and skills.

Recommendations

It is recommended that the welding procedure given in this report be distributed to and implemented by all maintenance units responsible for tactical bridge repair. In addition, it is recommended that this procedure be reevaluated in 5 years, after the new welding power supply is in general use.

*This situation appears to have been corrected; since the time of this study, an additional 50 hours of MIG and TIG welding have been added to the curriculum.

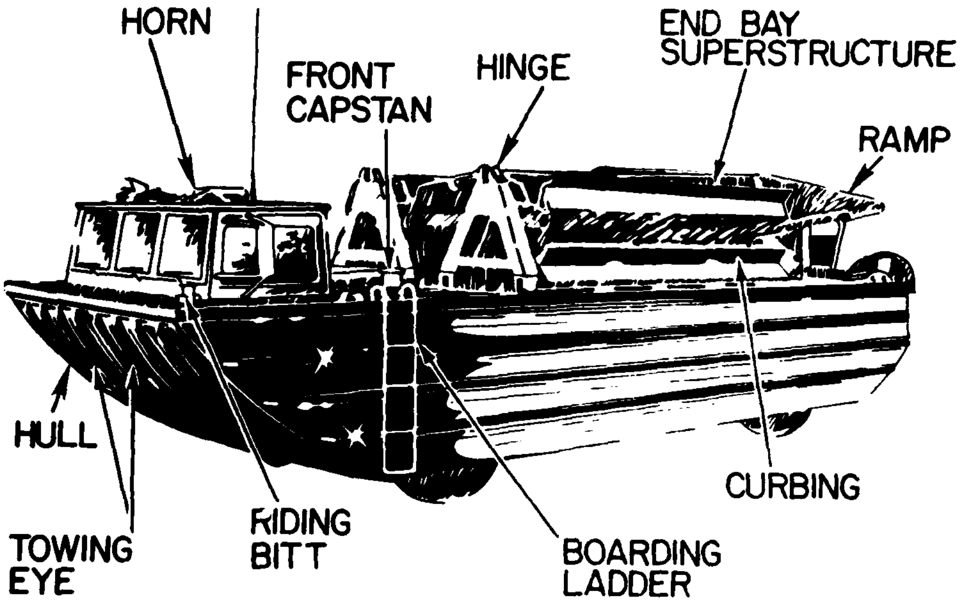


Figure 1. Transporter, mobile assault bridge/ferry with end bay superstructure installed.

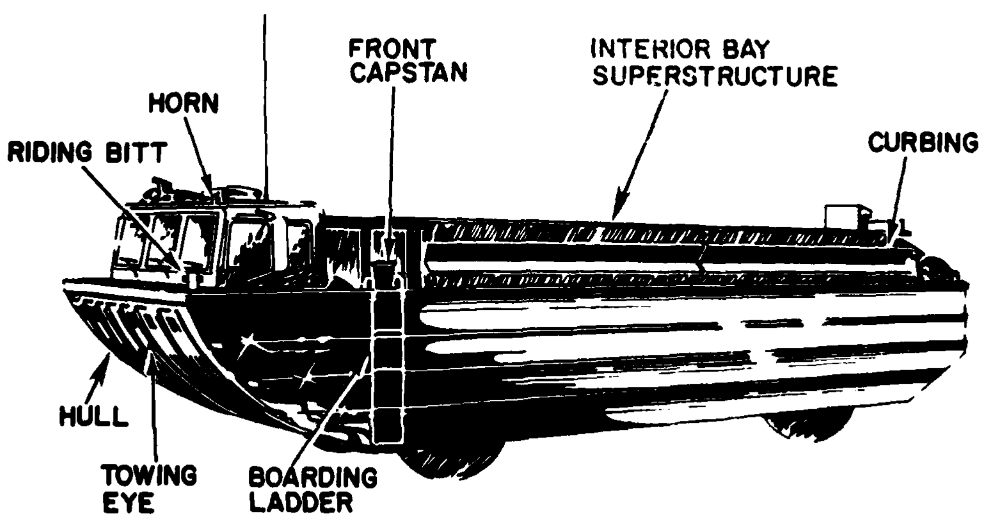


Figure 2. Transporter, mobile assault bridge/ferry with interior bay superstructure installed.

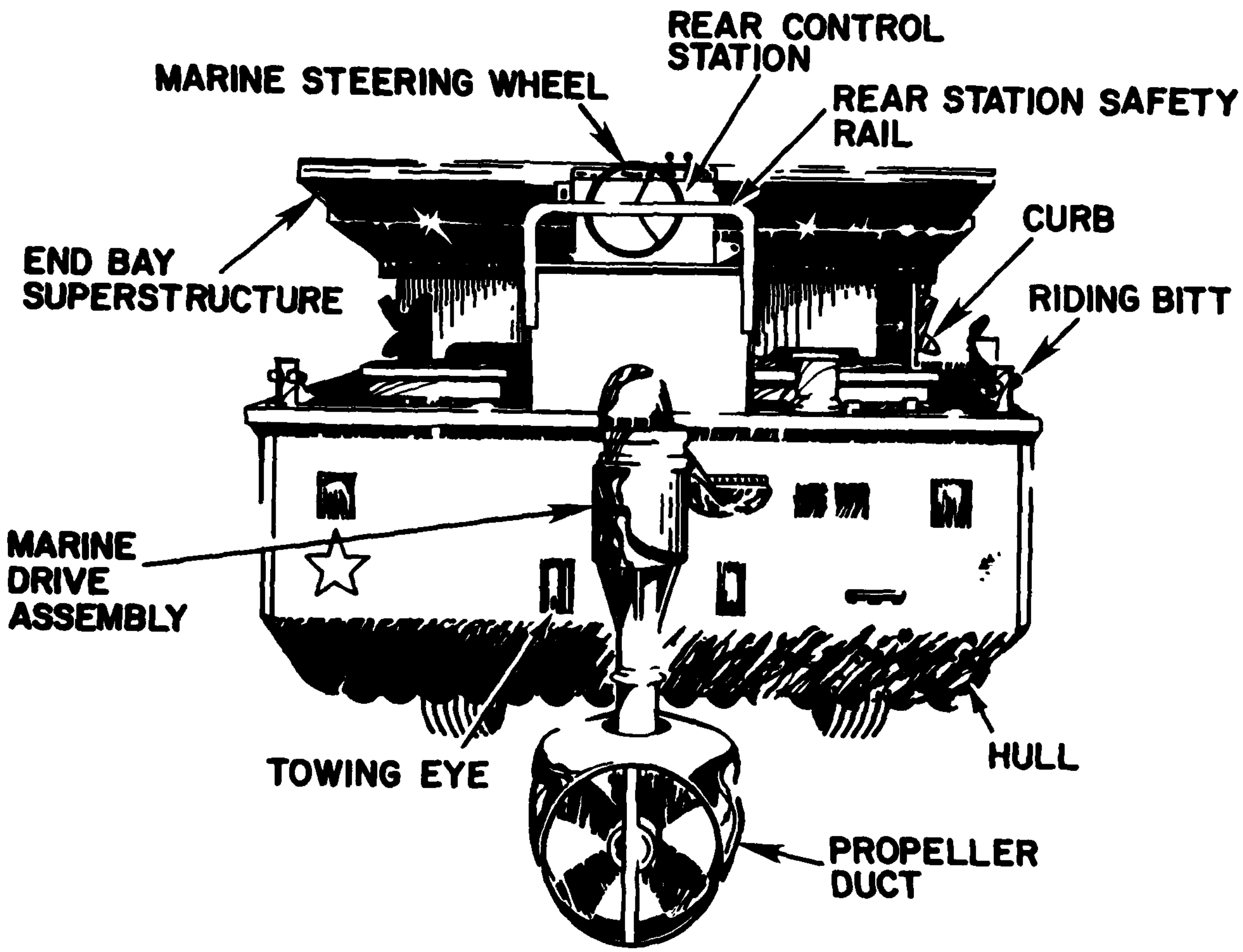


Figure 3. Stern end of transporter, mobile assault bridge/ferry with end bay superstructure installed.

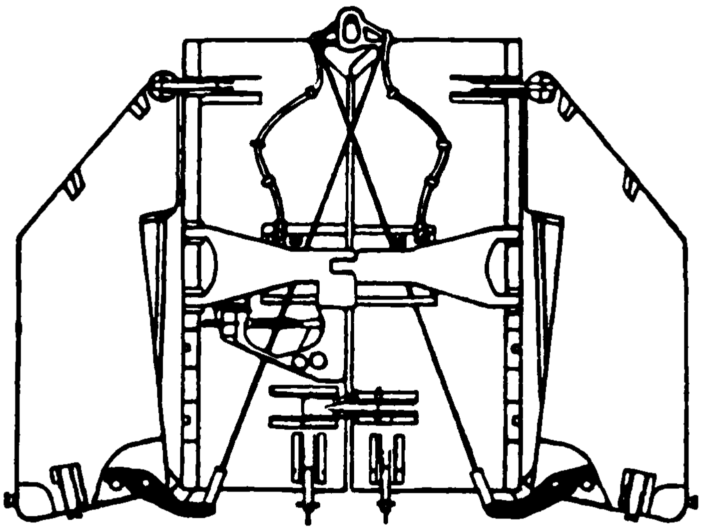


Figure 4. End view of folded interior bay section of the ribbon bridge.

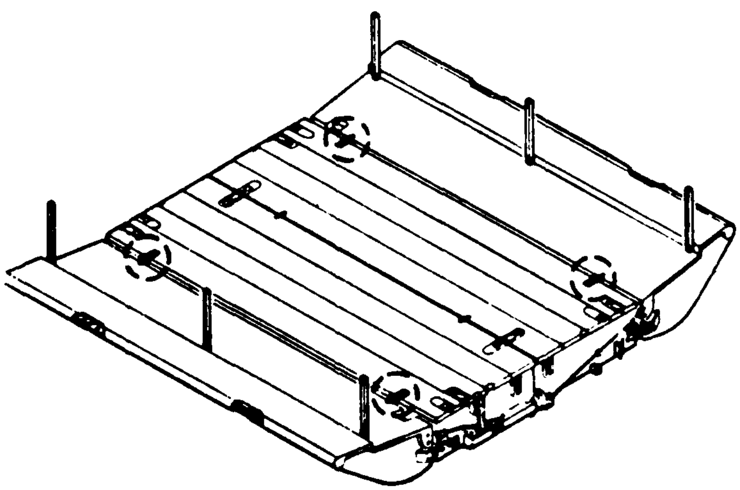


Figure 5. Interior bay section of the ribbon bridge.

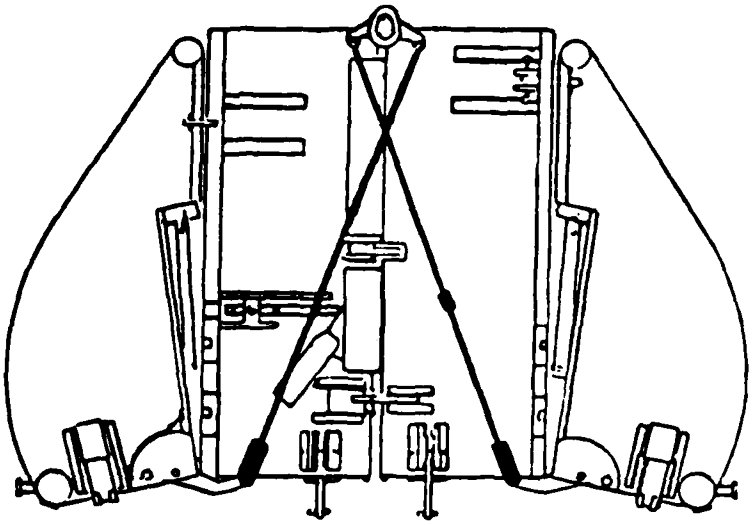


Figure 6. End view of folded ramp bay section of the ribbon bridge.

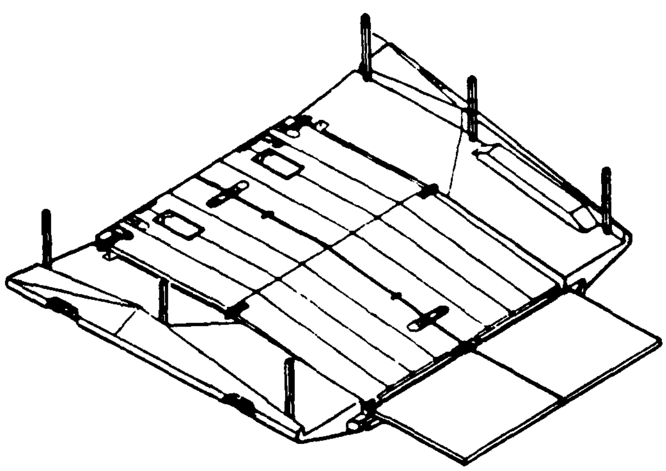


Figure 7. Ramp bay section of the ribbon bridge.

Figure 8. Off-loading the ribbon bridge from the transporter.

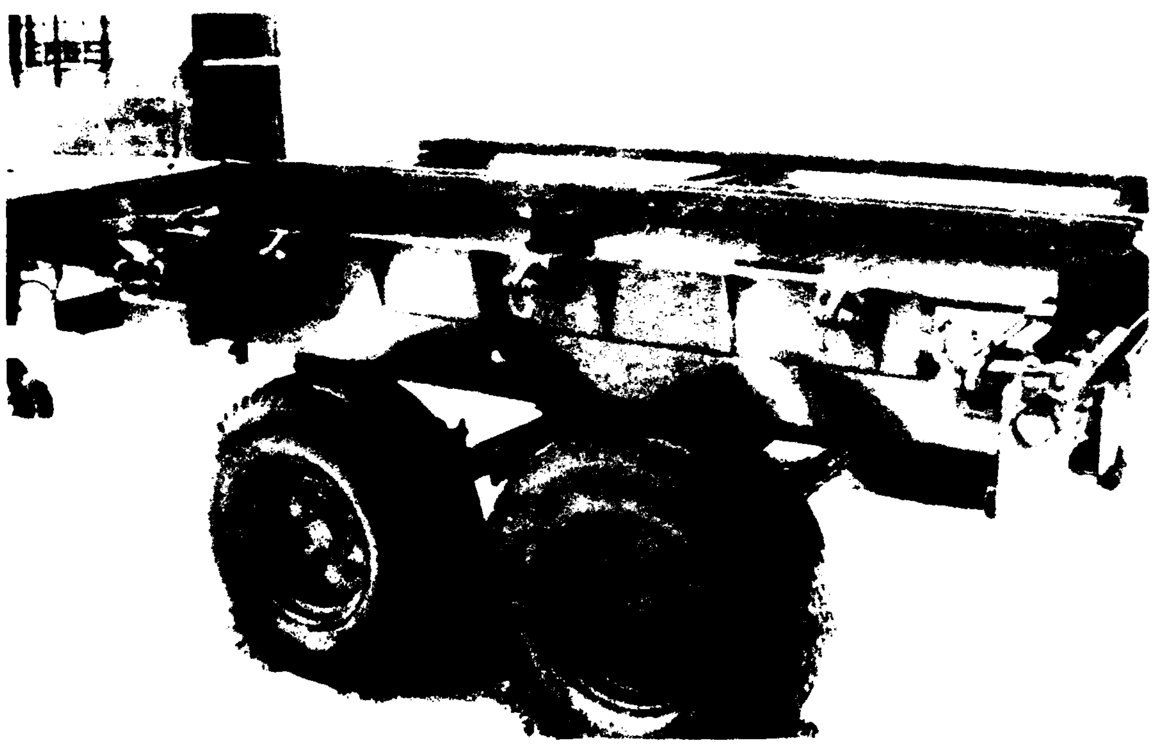


Figure 9. Trailer used to transport the medium girder bridge.

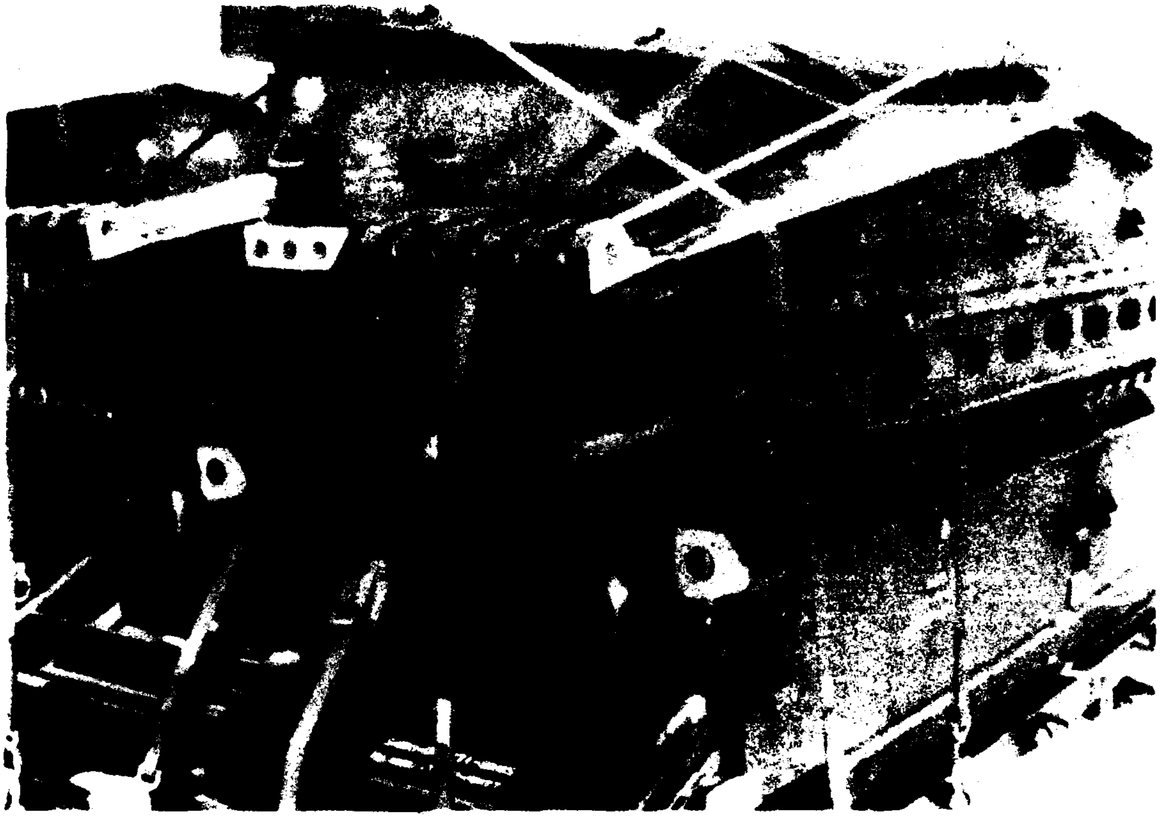


Figure 10. Medium girder bridge loaded for transport.

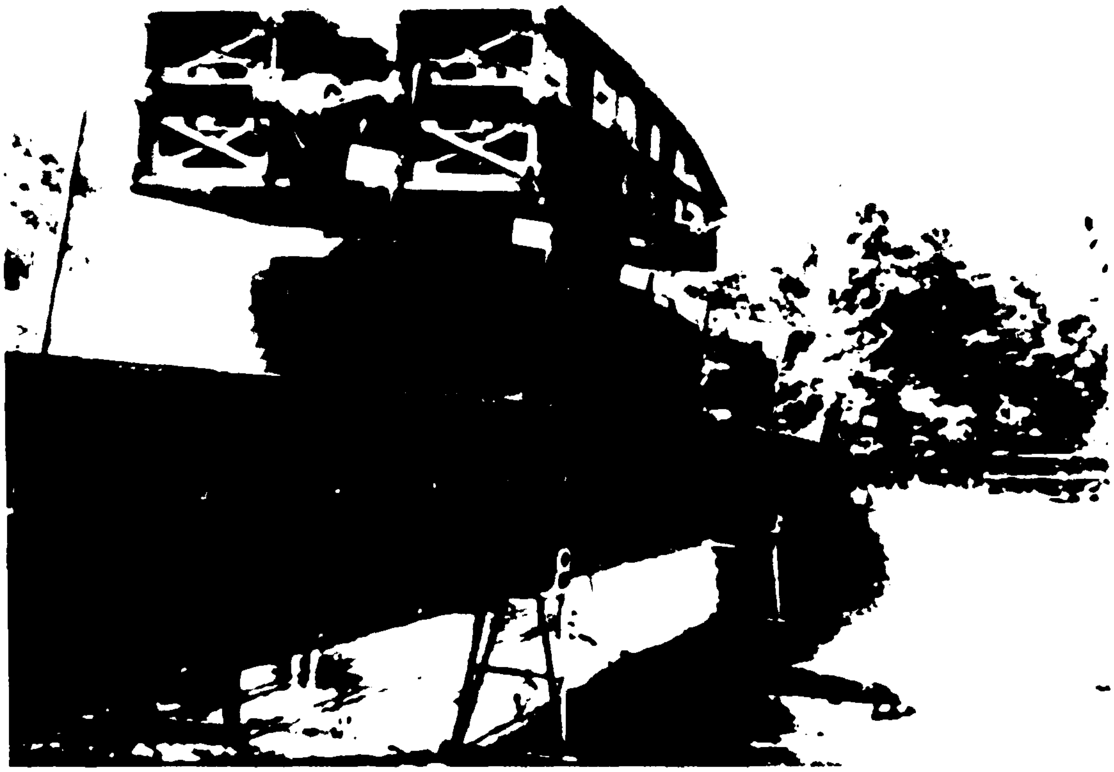


Figure 11. Erected medium girder bridge spanning a dry gap.

Figure 12. Patched hole on MAB transporter hull.

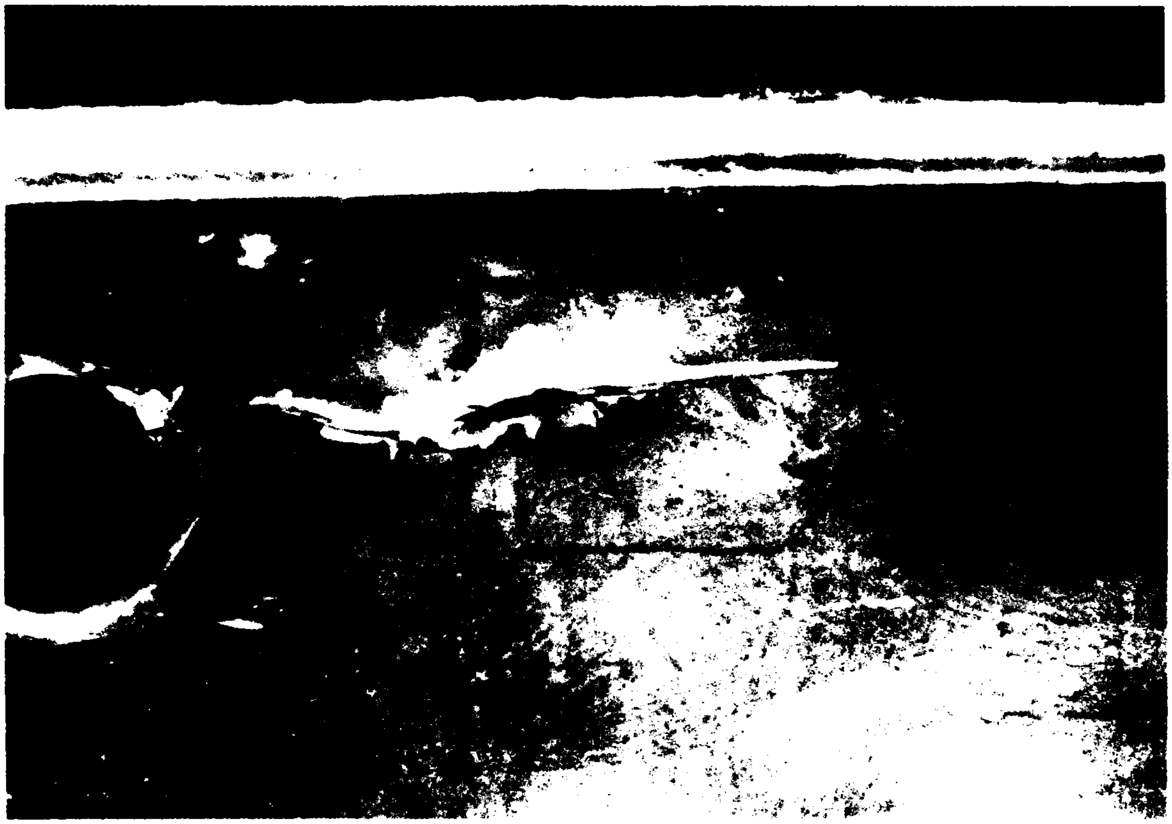


Figure 13. Typical type of puncture failure on the MAB and the ribbon bridge pontons.

Figure 14. Lifting cleat on medium girder bridge.

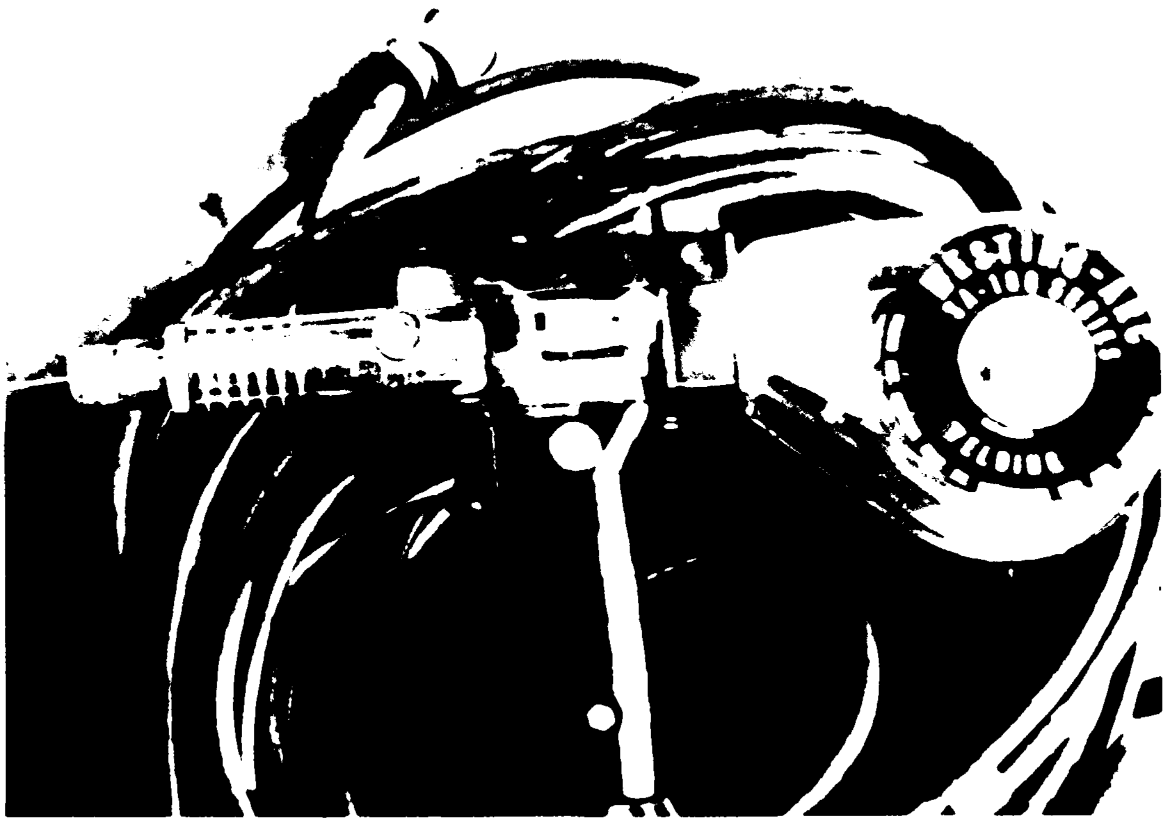


Figure 15. Gas metal-arc welding gun currently available through supply channels.

APPENDIX: FIELD REPAIR OF ALUMINUM MOBILE ASSAULT BRIDGE AND IMPROVED FLOAT BRIDGE (RIBBON BRIDGE)

This appendix outlines the field repair procedures to be used by engineer maintenance personnel for aluminum bridging components on the mobile assault bridge and the improved float bridge (ribbon bridge). It provides steps for repairing hull, cabin, and ponton damage to these two bridges. The information applies to the following equipment:

1. The hull and cabin of the mobile assault bridge transporter.

2. The pontons and corner pins of the improved float bridge (ribbon bridge).

Joint Preparation for Aluminum Welding

General

Sound welding practice requires that all foreign material be removed from areas to be welded. This includes dirt, loose metal particles, paint, moisture, thick oxide coatings, and any grease or oil.

Paint Removal

Remove all paint from the weld area and from about 3 in. (7.6 cm) to each side of the weld area to allow full visual inspection of the extent of failure. This will also insure that the heat of welding will not decompose the paint and cause a toxic atmosphere or interfere with making a good weld. Paint can be removed with solvents, wire brushing, or filing.

Hydrocarbons

Remove all oil, grease, and dirt from the joint area prior to welding to avoid poor weld fusion and excessive porosity. Petroleum base solvents are preferred for removing these contaminants. Naptha, toluene, and butyl alcohol are examples of good degreasing agents which evaporate quickly and leave little residue.

Oxide Removal

1. Aluminum oxide melts at 3700°F (2017°C), as compared to the base alloy which melts at about 1200°F (642°C); thus, unless minimized before welding, it can act as a "stop-off" to prevent weld fusion. This oxide increases in thickness when aluminum is subjected to thermal treatments and weathering. In some cases, an artificially thickened oxide or "anodizing" treatment is used as a paint base These thick oxides, which can become insulators, can prevent proper contact for passage of electrical current during welding. Thus, thick oxides must be removed from the weld area to permit proper weld fusion and often must also be removed in the area of the ground connection. Oxides may be removed by grinding, sanding, or wire brushing. Since grinding and sanding can imbed abrasive particles in the aluminum surfaces, wire brushing is the preferred method.

2. Manual wire brushing is an acceptable technique for oxide removal. The wire brush should be free from oil, grease, and rust. Power-driven wire brushes can also be used satisfactorily if *light* pressure is employed. A heavy pressure between the power-driven brush and the work piece can imbed foreign material into the surface or create folds in the surface which entrap oxide, hydrocarbons, etc. Clean the base metal with a solvent prior to wire brushing.

3. Weathering of bare aluminum and marine applications can produce hydrated oxide films and water stains. The moisture in the oxide can cause excessive weld porosity unless removed prior to welding. For these heavy oxide coatings, grinding or sanding followed by wire brushing is the preferred method of oxide removal.

Moisture

Moisture on the surface of the base metal or filler wire will decompose in the arc, producing hydrogen. The hydrogen dissolves readily in the molten weld metal and is a major cause of weld porosity. Preheat parts to a temperature not in excess of 250°F (120°C) to drive moisture or condensation from the weld area prior to welding. Because this is a thermal treatment and can increase the oxide coating thickness, wire brushing is required just before welding.

Weld Repair Techniques

General

Weld repair procedures are divided into four groups: patch repair, U-groove repair, cab repair, and pin repair. The first two methods can be used on either the transporter of the mobile assault bridge or the pontons of the ribbon bridge. The cab repair technique is used to repair the cab framing. The pin repair method is used to rebuild the supporting structure around the

pins on the ribbon bridge. These welding procedures are to be employed only after using the proper cleaning techniques as outlined in the previous section.

Patch Repair Procedure

Table A-1 and Figure A-1 outline specifications for this procedure. Particularly note the tack weld comments and the bead sequence and direction provided in Figure A-1. This technique will be used most often for patch repair because there is limited access to the interior of the transporter and the pontons.

U-Groove Repair Procedure

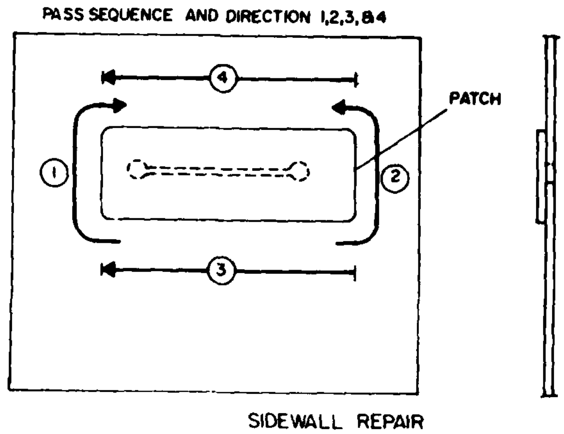
Because this technique uses a backing strip, it can be used only when there is access to the inside of the puncture or tear. Table A-2 and Figure A-2 outline specifications for this technique. Special considerations should be given to the bead sequence and bead application method shown in Table A-2 and Figure A-2.

Cab Repair Technique

This technique, which is used to repair structural damage to the mobile assault bridge cab, employs an anodized aluminum block as a backup for the weld. The anodizing allows the block to be used repeatedly as a backup. A single bead is usually sufficient to complete the repair, although if necessary, a second bead can be placed on the back side of the weld. Table A-3 outlines this technique, and Figure A-3 shows its layout.

Pin Repair Procedure

This method (see Table A-4) is used to build up the block support of the hinge pin on the ribbon bridge after it is worn down by the transporter rollers. Particularly note the weld bead sequence described in Figure A-4; if repairs are not done according to this sequence, excessive heat buildup could decrease the overall strength of the pin assembly.



Procedure:

1. Drill a 1/4-in. (.63-cm) hole at the ends of the crack. (This will prevent the crack from growing during the repair.)

2. Clean the weld area according to information provided on p. 23 of this appendix.

3. Prepare a patch of aluminum that covers the crack. Round the corners of the patch to about 1/2-in. (1.27-cm) radius. The patch should be shaped to fit any curvature of the hull or ponton.

4. Tack-weld the patch over the crack. If there is any area that does not fit flat against the hull or ponton, close the gap by welding a small fillet over it.

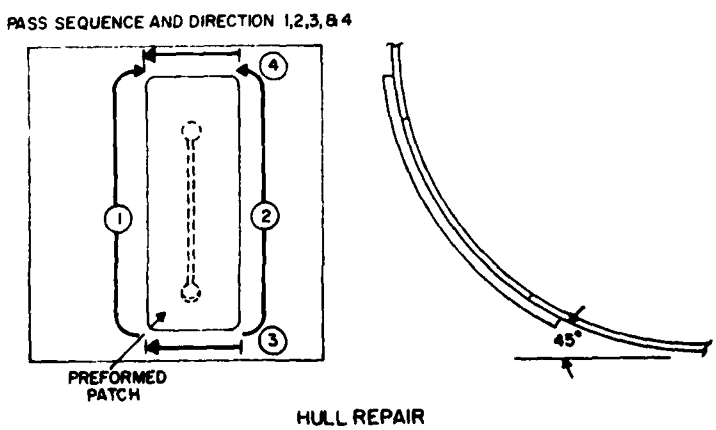
5. Weld the patch with parameters as shown in Table A-1 in the following sequence:

Passes 1 and 2. Start at either side at the bottom of the patch and work upward to the top. Feather out the weld across the top of the patch.

Pass 3. Start on the previous weld bead start, proceed across the weld, and end on the other weld bead.

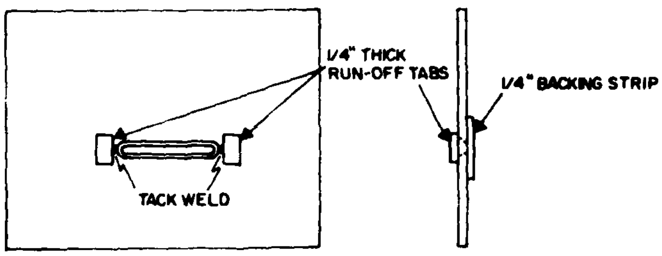
Pass 4. Start on the previous weld bead end, proceed horizontally across the weld, and end on the other weld bead finish.

NOTE: Passes 3 and 4 must overlap passes 1 and 2.



Procedure: Same as steps 1 through 5 shown for sidewall repair.

Figure A-1. Welding sequence for patch repair technique.



SIDEWALL REPAIR

Procedure:

1. Make a U-groove by opening and beveling the edges of the crack with a carbide deburring tool in an electric drill; see Table A-2 for details and dimensions.

2. Attach the backing strip to the inside of the weld by tack welding. The strip should be at least 1 in. (2.5 cm) longer than the crack and should fit the backside curvature.

3. Clean the weld area as noted on p. 23 of this appendix.

4. Tack-weld 1- X 2-in. (2.5- by 5-cm) rectangular tabs at each end of the groove, placing the tack between the groove and the tab.

5. Weld, using parameters in Table A-2 in the following sequence (refer to drawing at the bottom of Table A-2):

a. All weld beads must start and end on the run-off tabs.

b. Do the root pass with in-line oscillation (stroke approximately 1/4 in. [.63 cm]). Care should be taken to insure that there is good fusion to the backing strip.

c. The second pass is a straight stringer bead at the lower side of the groove.

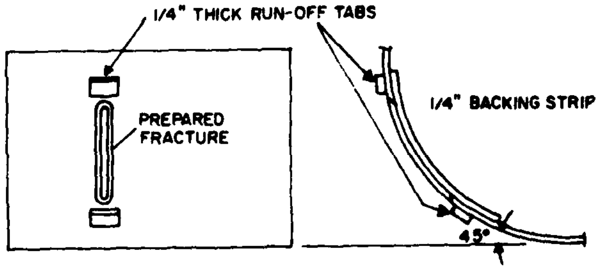
d. The final pass is a straight stringer bead at the top of the groove.

6. Remove run-off tabs by then bending up from the repair, and then smooth the area by filling or sanding. (The backing strip is attached permanently to the weld.)

NOTES:

1. Groove may require more than three passes, so repeat steps 5c and 5d until groove is flush with base material.

2. Repair technique can be done without the backing strip, but will require much greater operator skill.



HULL REPAIR

Procedure: Same as steps 1 through 6 for sidewall repair, except that the welding positions in step 4 are changed as follows:

a. The root pass should be 45° overhead with in-line oscillation.

b.* The second pass is made to the left of the root pass – straight stringer bead.

c.* The final pass is made to the right of the root pass – straight stringer bead.

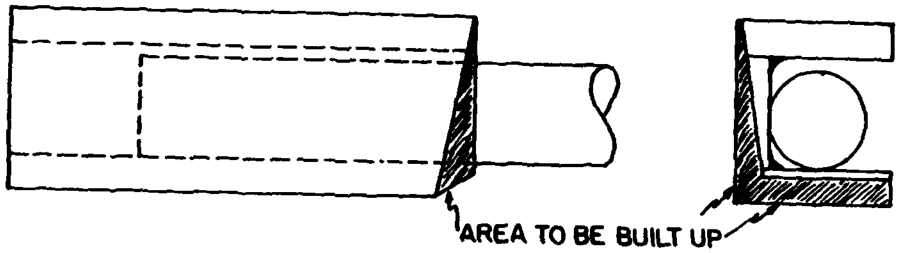
*The sequence of steps b and c can be reversed.

Figure A-2. Welding sequence for U-groove repair technique.

Procedure:

1. Tack-weld run-off tabs (about 1 × 2 in. [2.5 by 5 cm]) at each end of crack.
2. Clean the weld area according to information given on p. 23 of this appendix.
3. Clamp the anodized aluminum backup to one side of the weld.
4. Make one pass on the crack, using the parameters given in Table A-3. Starts and stops must be on the tabs.
5. Another pass may be required on the back side to clean up the root of the weld.

Figure A-3. Layout of weld with run-off tabs and weld backup.



Procedure:

1. Clean the weld area according to information given on p. 23 of this appendix.
2. Weld according to Table A-4 in the following sequence:

   a. Weld passes 1 and 2: vertical up with transverse weave over the worn surface.

   b. Weld passes 3 and 4: overhead with transverse weave over the worn bottom surface. Weld passes 5 and 6: overhead stringer to complete buildup of worn bottom surface.

   c. Weld passes 7 and 8: vertical stringers to complete buildup of the worn vertical surface.

   d. Dress the weld to its original contour, using suitable tools such as a disc grinder, file, burring tool, etc.

NOTES:

1. Interpass temperature should be maximum of 150°F (65°C).
2. Cap craters at the weld terminations with a button weld.
3. This technique is not applicable for all repairs. The procedure must be adapted to suit each condition.

Figure A-4. Welding sequence for hinge pin reinforcement repair technique.

Table A-1
Welding Procedure for Patch Welds

Welding Procedure No.: WPS-1   Date: Oct. 1980

Welding Process(es): GMAW   *Type(s): Semi-automatic*

Joints
Backing: No
Other: Lap fillet welds with aluminum patch

Base Metals
No. 5086 to No. 5086
Thickness Range: 3/16 to 1/4 inch

Filler Metals
Spec No. AWS A 5.10
AWS No. (Class) ER5356
Size of Electrode: .045 inch dia.
Size of Filler: 1 pound spool

Position
Position of Groove Fillet: 2F, 3F and 4F
Other: See Figure A-1

Preheat
Interpass Temp.: 150°F max.

Gas
Shielding Gas(es): Argon
Flow Rate: 60 CFH

Electrical Characteristics
Current: DC   Polarity: Reverse polarity
Amps (Range): 190–200   Volts (Range): 24–25

Technique (QW-410)
String or Weave Bead: String
Orifice or Gas Cup Size: 5/8 inch I.D.
Initial & Interpass Cleaning (Brushing, Grinding, etc.):
Wire brush (see p. 23)
Contact Tube to Work Distance: See footnote (1)
Multiple or Single Pass (per side): Single

Footnote (1): Contact tube set back 1/4 inch inside cup.

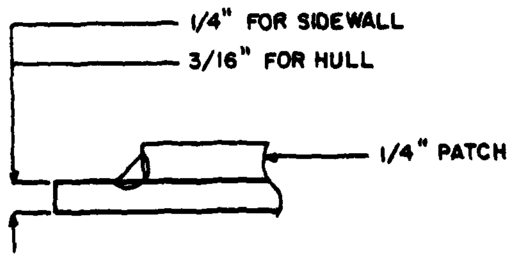


Table A-2
Welding Procedure for U-Groove Repair

Welding Process(es): GMAW

Type(s): Semi-automatic

Joints
Groove Design: U-Type
Backing: Yes
Backing material (Type): 1/4 inch - 5086 alloy
Other: Run-off tabs - .250 inch - 5086 alloy

Base Metals
No.: 5086 to 5086 and 5456 to 5456
Thickness Range: 3/16 to 1/4 inch

Filler Metals (QW-404)
Spec No. AWS A 5.10
AWS No. (Class): ER 5356
Size of Electrode: .047 inch dia.
Size of Filler: 1 pound spool

Position
Position of Groove: 2G, 3G and 4G

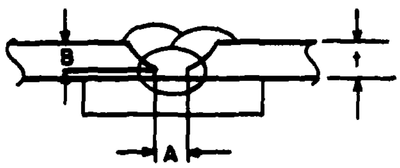
Preheat
Interpass Temp.: 150°F max.

Gas
Shielding Gas(es): Argon
Flow Rate: 60 CFH

Electrical Characteristics
Current: DC Polarity: Reverse polarity
Amps (Range): 190–200 Volts (Range): 24–25

Technique
String or Weave Bead: String
Orifice or Gas Cup Size: 5/8 inch I.D.
Initial & Interpass Cleaning (Brushing, Grinding, etc.): Wire brush (see p. 23)
Oscillation: In-line
Contact Tube to Work Distance: See footnote (1)
Multiple or Single Pass (per side): Multiple (3 passes)

Footnote (1): Contact tube set back .250 inch inside cup.



t	1/4"	3/16"
A	1/4"	3/16"
B	3/16"	1/8"

Table A-3
Welding Procedure for Cab Repair Technique

Welding Process(es): GMAW

Type(s): Semi-automatic

Joints
Groove Design: Butt
Backing: Yes
Backing material (Type): Anodized aluminum
Other: With 1/32 inch deep × 1/4 inch wide groove

Base Metals
No. 5086
Thickness Range: 1/8 inch

Filler Metals
Spec No. AWS A 5.10
AWS No. (Class): ER 5356
Size of Electrode: .047 inch dia.
Size of Filler: 1 pound spool

Position
Position of Groove: 2G and 3G
Other: See Figure A-3

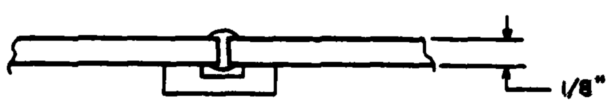
Preheat
Interpass Temp.: 150°F max.

Gas
Shielding Gas(es): Argon
Flow Rate: 60 CFH

Electrical Characteristics
Current: DC Polarity: Reverse polarity
Amps (Range): 170–180 Volts (Range): 22–23

Technique (QW-410)
String or Weave Bead: String
Orifice or Gas Cup Size: 5/8 inch I.D.
Initial & Interpass Cleaning (Brushing, Grinding, etc.): Wire brush (see p. 23)
Contact Tube to Work Distance: See footnote (1)
Multiple or Single Pass (per side): Single

Footnote (1): Contact tube set back .250 inch inside cup.



Cabin Frame Size .125 × 18 × 24 inch 5083-F – See Figures 13 and 14.

Table A-4
Welding Procedure for Hinge Pin Reinforcement Build-Up Technique

Welding Process(es): GMAW

Type(s): Semi-automatic

Base Metals
No. 5456
Thickness Range: 3/8 inch

Filler Metals
Spec No. AWS A 5.10
AWS No. (Class): ER 5356
Size of Electrode: .047 inch dia.
Size of Filler: 1 pound spool

Position
Position: 3G and 4G

Other: See below and Figure A-4

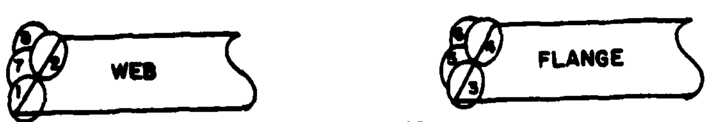
Preheat
Interpass Temp.: 150°F max.

Gas
Shielding Gas(es): Argon
Flow Rate: 60 CFH

Electrical Characteristics
Current: DC   Polarity: Reverse polarity
Amps (Range): 160–170   Volts (Range): 22–23

Technique (QW-410)
String or Weave Bead: Both
Orifice or Gas Cup Size: 5/8 inch I.D.
Initial & Interpass Cleaning (Brushing, Grinding, etc.): Wire brush (see p. 23)
Oscillation: Yes
Contact Tube to Work Distance: See footnote (1)
Multiple or Single Pass (per side): Multiple (4 passes)

Footnote (1): Contact tube set back .250 inch inside cup.



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